

Endoscopic Aqueductoplasty Technique and Preliminary Results

Endoskopik Akuaduktoplasti Tekniđi ve İlk Sonular

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Abstract: Objective: Neuroendoscopic aqueductoplasty presents an effective alternative to third ventriculostomy for the treatment of hydrocephalus caused by stenosis of the aqueduct of Sylvius. There have been few reports in the past decade with promising results. Here we report our preliminary experience, describe the technique for endoscopic aqueductoplasty, and review the pertinent literature.

Methods: Four patients with hydrocephalus related to aqueductal stenosis who underwent neuroendoscopic aqueductoplasty procedure in our neuroendoscopy unit were presented. Postoperatively, patency of the restored cerebrospinal fluid flow was confirmed with cine phase-contrast MR imaging.

Results: In three cases endoscopic aqueductoplasty was performed successfully and there was no need for third ventriculostomy. In one case that exhibited a long-segment aqueductal stenosis, aqueductoplasty procedure had to be abandoned and third ventriculostomy was performed. The only surgical complication was an asymptomatic forniceal contusion in one patient. None of the patients required shunting after the neuroendoscopic procedure.

Conclusion: Our preliminary results show that neuroendoscopic aqueductoplasty is an effective alternative to third ventriculostomy for the treatment of hydrocephalus caused by short or membranous stenoses of the aqueduct of Sylvius. We also suggest that cine phase-contrast MR imaging is a sensitive technique for assessing postoperative CSF flow through the aqueduct.

Key Words: aqueductal stenosis, endoscopic aqueductoplasty, hydrocephalus, neuroendoscopy.

Özet: Ama: Günümüzde akuadukt stenozuna bađlı hidrosefali olgularında; nöroendoskopik akuaduktoplasti tekniđi, endoskopik üçüncü ventrikülostomiye iyi bir alternatif sunmaktadır. Sayıları az olmasına karŐın, bu konuda son dekad içerisinde, umut verici sonular bildirilmektedir. Bu yazıda akuaduktoplasti ile ilgili deneyim ve sonularımızın yanısıra endoskopik akuaduktoplasti tekniđimiz ve ilgili literatr de gözden geçirilmiŐtir.

Yöntem: Nöroendoskopi ünitemizde akuadukt stenozuna bađlı hidrosefali tanısı ile endoskopik akuaduktoplasti uygulanan dört olgu sunulmuŐtur. Olgular postoperatif dönemde sine faz-kontrast MR incelemesi ile deđerlendirilmiŐtir.

Bulgular: Ü olguda endoskopik akuaduktoplasti baŐarı ile uygulanmıŐ ve üçüncü ventrikülostomiye gerek duyulmamıŐtır. Uzun-segment akuadukt stenozu olan bir olguda ise akuoduktoplasti tamamlanamamıŐ ve üçüncü ventrikülostomi tercih edilmiŐtir. KarŐılaŐılan tek komplikasyon bir olguda asemptomatik forniks kontzyonudur. Nöroendoskopik prosedrlerden sonra hi bir hastada Őant cerrahisi gerekmemiŐtir.

Sonu: İlk deneyimlerimiz, kısa ve membranöz akuadukt stenozlarına bađlı hidrosefali olgularında; endoskopik akuaduktoplastinin, üçüncü ventrikülostomiye iyi bir alternatif oluŐturduđunu göstermektedir. Ayrıca bu teknikten sonra, restore edilen akuadukt kanalındaki likör akımının kontrol için sine faz-kontrast MR incelemesinin duyarlı bir tetkik olduđunu düşünyoruz.

Anahtar Sözcükler: akuadukt stenozu, endoskopik akuaduktoplasti, hidrosefali, nöroendoskopi.

INTRODUCTION

There are a number of well-established and effective surgical techniques for treating non-communicating hydrocephalus caused by aqueductal stenosis. Third ventriculostomy is currently the treatment of choice and favorable results have been reported (1,2,3). To date, there are only a few reports in the literature on endoscopic aqueductoplasty (4,5,6,7,8).

This article reports the cases of four patients with aqueductal stenosis who underwent endoscopic aqueductoplasty in our neuroendoscopy unit. We describe our technique and discuss the efficacy of endoscopic aqueductoplasty.

PATIENTS AND METHODS

Four patients with hydrocephalus related to aqueductal stenosis underwent endoscopic aqueductoplasty in our neuroendoscopy unit between May 2002 and August 2002.

Patient 1 was a 23-year-old male with complaints of headache, nausea and mental deterioration. His magnetic resonance (MR) images demonstrated triventricular hydrocephalus and edema surrounding the lateral ventricles.

Patient 2 was an 8-month-old girl who was referred to our department for neuromotor retardation, seizures, unilateral abducens palsy and weakness of upward gaze. Her cranial vault was enlarged. In this case, MR imaging showed triventricular hydrocephalus, aqueductal stenosis and a small posterior fossa.

Patient 3 was a 2-year-old male who had been introduced a ventriculoperitoneal shunt at 1 month of life for treatment of non-communicating hydrocephalus. He was referred to our clinic with symptoms of increased intracranial pressure due to mechanical obstruction of the shunt. The patient had an enlarged cranial vault. His MR images showed triventricular hydrocephalus and aqueductal stenosis.

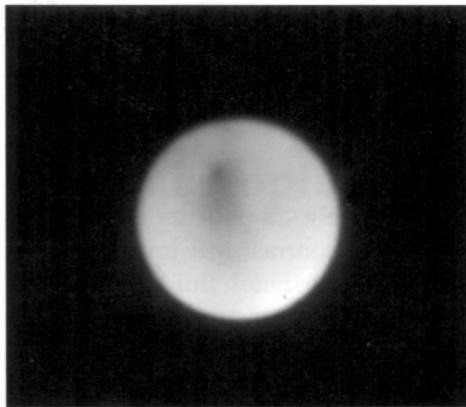
Patient 4 was a 24-year-old male who presented with progressive mental deterioration.

He had developed spontaneous intraventricular hemorrhage 3 weeks prior to presentation. In this case, MR imaging revealed triventricular hydrocephalus and edema surrounding the lateral ventricles.

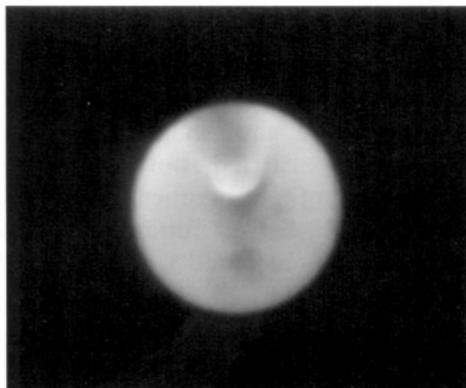
Preoperatively, all patients were investigated with cine phase-contrast MR imaging to evaluate aqueductal cerebrospinal fluid (CSF) flow. This was done using a 1.5-tesla MR imaging unit (Philips Gyroscan Intera Master 1.5T, Best, The Netherlands). Cine phase-contrast MR imaging revealed lack of an aqueductal flow-void sign in all cases.

Endoscopic Technique:

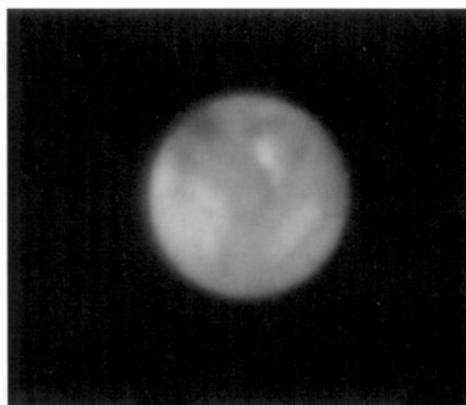
The patient was placed in supine position with the head tilted slightly forward. The head was placed in a horse shoe-shaped headrest. All procedures were carried out under general anesthesia using a Storz neuroendoscopic system (Karl Storz GmbH & Co., Tuttlingen, Germany). Each operation was recorded with video imaging (Karl Storz Telecam, SL). In all operations the burr hole was made based on information obtained from sagittal MR images. As described elsewhere [6], the entry point was selected to allow access to the floor of the third ventricle as well as to the aqueduct. Thus, the burr hole was 4 cm anterior to the coronal suture in Patients 1 and 4, and 3 cm anterior to the coronal suture in Patients 2 and 3. Once the dura was incised, the trocar was inserted freehand into the lateral ventricle. The obturator of the trocar was removed and, after releasing some CSF, the 0° rigid rod lens endoscope (4.0 mm) was introduced. After exploration of the lateral ventricle, the foramen of Monro and its surrounding structures were identified. Lactated Ringer's solution at 37 °C was used for irrigation. Minor hemorrhages ceased spontaneously after a few minutes of simple irrigation with a syringe attached to the irrigating catheter. The endoscope was advanced through the foramen of Monro into the third ventricle. First, to assist with orientation, the anatomical landmarks within the third ventricle (the mamillary bodies, tuber cinereum and the massa intermedia) were identified. The endoscope was then navigated beneath the massa intermedia and the landmarks of the posterior part of the third ventricle (the pineal recess, posterior commissure and the aditus of the aqueduct of



1a



1b



1c

Figure 1: Intraoperative photographs produced from digital video recordings of the procedure: a) Neuroendoscopic view of the entry of the aqueduct of Sylvius; b) Balloon catheter being gently inserted into the aqueduct; c) Neuroendoscopic view of the fourth ventricle and its choroid plexus.

Sylvius) were identified. Next, the endoscope was slowly moved towards the aqueduct for close inspection (Figure 1a). Aqueductoplasty was performed with the aid of a 2.5-F balloon catheter (Cordis Europass 530-530E, Roden, The Netherlands). The uninflated balloon catheter was advanced beyond the tip of the endoscope, and was then gently passed through the aditus of the aqueduct into the aqueduct (Figure 1b). The lumen of the aqueduct was restored by careful inflation of the balloon. After the balloon was deflated and the catheter was retracted into the working channel of the endoscope, the aqueduct was inspected to confirm patency and free flow of CSF. Any remaining membranous structures were opened with the "water-jet" technique. The endoscope was slowly moved through the aditus of the aqueduct for close inspection. We were able to inspect the fourth ventricle in Patients 1, 2 and 4 (Figure 1c). Finally, the endoscope was withdrawn and the burr hole was packed with gelatin sponge. The galea was tightly sutured and the skin was closed with staples.

RESULTS

In three cases (Patients 1, 2 and 4), endoscopic aqueductoplasty was performed successfully and there was no need for third ventriculostomy. In Patient 3, the aqueductoplasty procedure had to be abandoned due to problems detailed below, and third ventriculostomy was performed. The mean duration of the endoscopic procedures was 43 minutes. None of the procedures were abandoned due to bleeding or technical problems, and there was no endoscopy-related mortality. The only surgical complication was an asymptomatic fornical contusion in one patient.

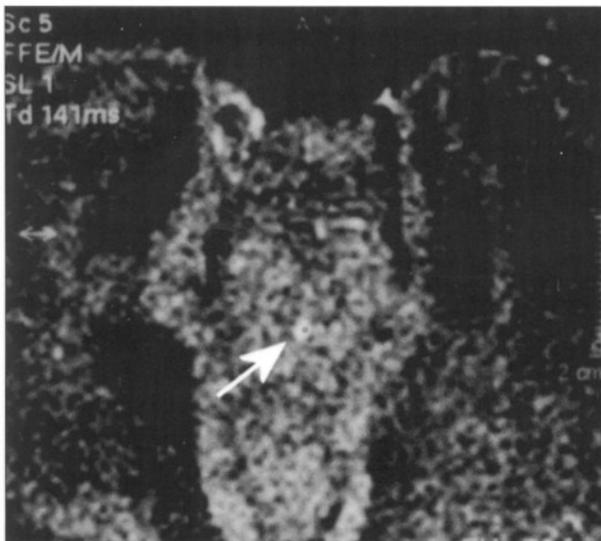
Patient 3 exhibited long-segment aqueductal stenosis. In this case, after the balloon catheter was navigated through the aditus of the aqueduct, it was impossible to advance it any further. The aqueductoplasty procedure was stopped at this stage, and third ventriculostomy was performed to bypass the aqueduct. The ventriculoperitoneal shunt system was removed after third ventriculostomy was complete.

In Patient 4, the aditus of the aqueduct was plugged by an organized hematoma. After this was reopened by inflating the balloon catheter, we

observed that the aqueduct lumen contained several membranous strictures. These were successfully opened with the "water-jet" technique.

In the postoperative period and during follow-up, all the patients experienced relief of symptoms and showed clinical improvement with respect to preoperative signs of increased intracranial pressure. None of the individuals required shunting. The follow-up periods were 5 months for Patient 1, 4 months for Patient 2, and 2 months for Patients 3 and 4.

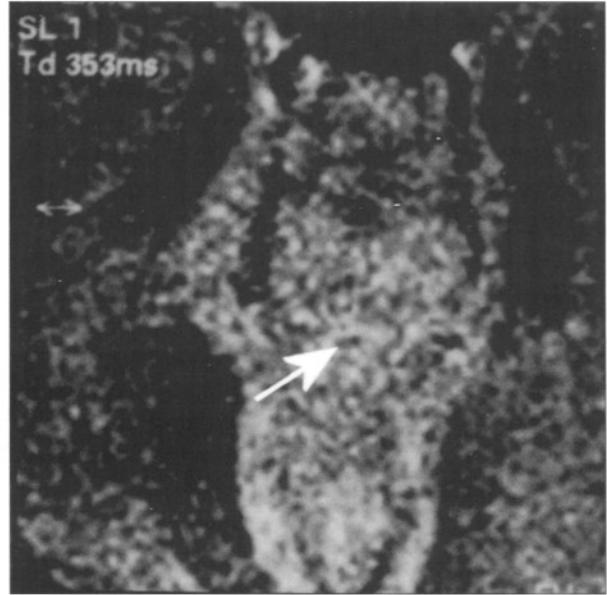
Postoperatively, patency of the restored aqueducts and the ventriculostomy site was confirmed with cine phase-contrast MR imaging. In Patients 1, 2 and 4, a CSF flow-void sign was detected within the aqueduct, indicating aqueductal patency (Figures 2a and 2b).



2a

DISCUSSION

Treatment of hydrocephalus has always been a challenge in neurosurgical practice. Despite improvements in CSF shunt systems and operative techniques, failure rates are still high and numerous types of complications still occur. In light of these problems, shunts should be avoided whenever possible. As an alternative, endoscopic third ventriculostomy has been gaining popularity since the late 1980s, and is currently the method of



2b

Figure 2: Axial phase contrast images obtained perpendicular to the aqueduct (TR: 21 ms, TE: 8.1 ms, flip angle 10°, scan thickness: 4 mm): a) Hyperintense signal within the aqueduct (arrow) indicating cerebrospinal fluid systole (caudal flow); b) Hypointense signal within the aqueduct (arrow) indicating cerebrospinal fluid diastole (cranial flow).

choice for managing non-communicating hydrocephalus. As mentioned above, to date only a few reports have been published on endoscopic aqueductoplasty (4,5,6,8). However, in the past 10 years, the results with neuroendoscopic restoration of the aqueduct of Sylvius have been promising. (Table I).

In their report on a series of 17 patients with hydrocephalus caused by aqueductal stenosis, Schroeder and Gaab recommended endoscopic aqueductoplasty as a valuable alternative to third ventriculostomy. (6). Another study noted some advantages of aqueductoplasty over third ventriculostomy (7): 1) restoration the physiological CSF pathway; 2) no risk of major vessel injury; 3) no resultant arachnoid adhesions around the aqueduct; and 4) easy eradication of strictures within the aqueduct.

However endoscopic aqueductoplasty is not an easy or routine technique, and thus cannot be recommended for neuroendoscopy beginners. It is important to remember that the nuclei of cranial nerves III, IV and V, as well as the decussation of

Table I: A summary of the literature on endoscopic aqueduct restoration.

Series	Number of Patients	Operative Technique	Mortality(%)	Success Rate (%)
Oka et al., 1993 (ref. No 5)	4	Aqueductoplasty with v catheter + simultaneous third ventriculostomy	0	75
Teo et al., 1996 (ref. No 8)	4	Stenting	0	100
Manwaring and Fritsch, 1998 (ref. No 4)	8	Aqueductoplasty with balloon catheter, stent	0	100
Schroeder and Gaab, 1999 (ref. No 6)	17	Aqueductoplasty with balloon catheter, stenting, simultaneous third ventriculostomy	0	69

the trochlear nerve, the brachium conjunctivum of the superior cerebellar peduncle, and the fasciculus longitudinalis medialis are just millimeters away from the aqueduct. All of these elements may be easily injured by inappropriate manipulation.

With respect to postoperative complications, in the above-mentioned series of 17 cases, Schroeder and Gaab reported asymptomatic contusion of the fornix in one patient, aqueductal roof injury in two patients (one with a transient ocular abnormality and one with a permanent ocular abnormality), and two cases of transient ocular abnormalities that resolved within 3 to 4 weeks post-surgery (6). We experienced a contusion of the fornix in one patient, which resulted in no morbidity.

Five of the patients in Schroeder and Gaab's series exhibited long-segment stenosis (segment 5 mm or longer) (6). Four of these individuals were treated with third ventriculostomy alone, or underwent third ventriculostomy in addition to neuroendoscopic restoration of the aqueduct. One of these patients sustained an injury to the aqueductal roof that resulted in permanent diplopia. The authors concluded that re-opening the aqueduct in cases of long-segment stenosis carries a high risk of midbrain injury and

associated neurological deficits, such as dysconjugate eye movements, Parinaud's syndrome, and oculomotor or trochlear palsy. They advised against endoscopic aqueductoplasty in patients with long-segment stenosis. Our preliminary experience supports this, as we found it impossible to perform aqueductoplasty in a patient with long-segment aqueductal stenosis (Patient 3). In this case, we abandoned the aqueductoplasty procedure based on the dynamics of the intraoperative anatomy, and performed third ventriculostomy instead.

Cine MR imaging has been recommended for evaluating the patency of third ventriculostomies (2). Schroeder et al. were the first to analyze aqueductal CSF flow after endoscopic aqueductoplasty using cine phase-contrast MR imaging (7). They reported this technique to be quite sensitive for evaluating aqueductal flow after the procedure. Our experience in our four cases was in line with this.

The ultimate goal of contemporary neurosurgery is to replace shunt systems with neuroendoscopic procedures that avoid all use of CSF shunts. Neuroendoscopic aqueductoplasty is a promising technique for restoring the anatomical CSF pathway. Although this method carries

potential risks that cannot be overestimated, problems can be avoided in the hands of an experienced neuroendoscopist. Studies with longer follow-up periods are needed to evaluate the long-term patency of aqueducts restored by this method.

CONCLUSION

Endoscopic aqueductoplasty is an effective alternative to third ventriculostomy in the treatment of hydrocephalus caused by short or membranous stenosis of the aqueduct. In cases with long-segment occlusion, third ventriculostomy should be considered. Our preliminary results show that endoscopic aqueductoplasty is an effective method of restoring the anatomical patency of the aqueduct of Sylvius. We also suggest that cine phase-contrast MR imaging is a sensitive technique for assessing postoperative CSF flow through the aqueduct.

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